International Journal of Human–Computer Interaction

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/hihc20

Social Presence Awareness Visualization in a Collaborative Videogame

Maria Teresa Cepero, Luis G. Montané-Jiménez, Guadalupe Toledo-Toledo, Betania Hernández-Ocaña & Carlos Alberto Ochoa

INTERNATIONAL JOURNAL OF HUMAN–COMPUTER INTERACTION
https://doi.org/10.1080/10447318.2022.2132357

Social Presence Awareness Visualization in a Collaborative Videogame

Maria Teresa Cepero[a], Luis G. Montané-Jiménez[a], Guadalupe Toledo-Toledo[b], Betania Hernández-Ocaña[c], and Carlos Alberto Ochoa[a]

[a]Facultad de Estadística e Informática, Universidad Veracruzana, Xalapa, Mexico; [b]Computer Engineering Department, Universidad del Istmo, Santo Domingo Tehuantepec, Mexico; [c]Academic Division of Information Sciences and Technologies, Universidad Juárez Autónoma de Tabasco, Villahermosa, Mexico

ABSTRACT

The awareness information in collaborative systems supports the interaction between people. However, traditional awareness systems are limited to mechanisms that display data often isolated from the context of social interaction and do not fully reflect the individual relevance of a person (social presence) in the collaborative activity. Therefore, proposing more dynamic and efficient tools to facilitate the acquisition and presentation of social presence information is convenient. This research proposes a social presence visualization system and its conceptual architecture and develops a user-centered prototype. The prototype integrates functions that let the user select different representations of social presence (pictogram, bar chart, donut chart, and radial). We used the prototype in a collaborative video game (AssaultCube-CX) to study the effects of social presence visualization on users' performance. We studied the social presence of 12 Mexican volunteers by recording their activities during the tests to analyze their social presence. The social presence quantitative analysis indicates that the visualization of social presence during the collaborative activity increase awareness of social presence and improves team performance in most cases.

1. Introduction

Groupware Systems (GS) support team activities in which a group of users interacts to combine their skills, abilities, and work to achieve a common goal (Herrera et al., 2014). GSs assist the collaborative working process through awareness information that helps keep people aware of events beyond their current tasks (Dourish & Bellotti, 1992), for example, understanding who is participating, where they are, what they say, and what they do (Storey et al., 2005). This insight helps people make inferences about the intentions, actions, or even emotions of others, and provides a context for group activities and social interactions (Markopoulos & Mackay, 2009).

Studies in several contexts, including control rooms, medical environments, and general offices, have shown how sensitive people are to what others are doing, whether by overhearing talk or overseeing another's activities (Luff et al., 2008). In remote collaborative environments, some of these natural resources that people use to overview the team activity are lost. In these particular contexts, where people work together while geographically spread, awareness support compensates the inefficiencies related to remote communication, provides information to help people maintain awareness of the people and events in the shared environment, and reduces the effort needed to coordinate activities and resources in a collaborative activity (Antunes et al., 2014).

Awareness of the situation during a collaborative activity evolves from the information that the system provides. Within the awareness information that a system can offer, social presence awareness information plays an important role in supporting collaborative work. Social presence awareness provides the understanding of the relevance of users when they are participating in a collaborative activity (Montané-Jiménez et al., 2015).

Visualization is one of the strategies used to display social presence information and create awareness knowledge. Awareness visualization mechanisms are meant to display awarness information in a visual and meaningful way to support decision-making when users are participating in a collaborative activity. For example, in a competitive context such as video games, performance awareness from a team support perspective (social presence) is considered useful information to the players, who by the nature of the game, have to coordinate, develop team strategies, and make decisions quickly. These visual means will help decision-makers to better understand team member interactions and contributions to the collaborative activity (Montané-Jiménez, 2016; Pouryazdan et al., 2017).

Researchers have evaluated social presence in diverse task settings (Liang et al., 2015; Montané-Jiménez et al., 2015; Xu et al., 2016). Although the information is captured automatically, analysis and visualization of the social presence are done" manually" by the researchers, which is time-consuming. There are some attempts to develop performance awareness visualization mechanisms that weigh teamwork, for example Gerosa et al. (2003) and Xu et al. (2016). However, these attempts are limited in terms of implementation as the

CONTACT Luis G. Montané-Jiménez lmontane@uv.mx Facultad de Estadística e Informática, Universidad Veracruzana, Xalapa, Mexico

information is not presented in a timely manner or is presented in a way unsuitable for the user, like tables difficult to assimilate during collaborative activity. Furthermore, little effort has been put into the information presentation and the evaluation of the effects of social presence visualizations in user perception and performance.

Social presence information is traditionally presented in a non-user-centric way, which can cause usability limitations and increase the user's cognitive load, such as distractions that negatively affect the user's performance during the activity. Considering the challenges associated with visualizing social presence, the following research questions arise: How to present social presence information in a collaborative video game? What is the effect of social presence visualization on users' performance in a collaborative video game?

This paper aims to analyze different ways of presenting social presence, propose a social presence visualization system and its conceptual architecture, and develop a user-centered prototype considering PC players as the target population. The prototype integrates functions that let the user select different visualization techniques to represent social presence (pictogram, bar chart, donut chart, and radial). The collaborative videogame AssaultCube-CX is used as a case study to analyze the effects and preferences of social presence visualization. We conducted an exploratory study to examine the social presence of a group of 12 volunteers from Mexico while playing AssaultCube-CX with and without social presence visualization.

In this article, Section 2 analyzes the concept of social presence, describes the process of awareness information visualization, and examines the state of the art of awareness visualization techniques used in GS and collaborative video games. Section 3 presents a proposal for a social presence visualization system. The proposal includes conceptual system architecture and a prototype of a social presence awareness visualization system developed under a user-centered design approach. Section 6 presents the experimental evaluation of the prototype and the outcomes reported. In Section 7 the results of the research are discussed and finally, Section 9 presents the conclusions.

2. Background

The concepts of social presence awareness and visualization are presented below. In addition, we present a review of the awareness visualization techniques and mechanisms in groupware systems. Finally, we describe the main visualizations of performance and social presence awareness in collaborative video games.

2.1. Social presence awareness

Currently there is no universally accepted definition of social presence awareness. Biocca et al. (2003) state that social presence is the sense of being together with another. This social presence is not a physical fact, but a psychological one. According to Hudson and Cairns (2016), the term social presence is used to understand social connections through media such as digital games but also including virtual environments. This connection or feeling of being together is the product of a shared involvement, whether that involvement consists of explicit communication, working together, or simply being aware that actions are occurring in a shared context (Lankes et al., 2016). As Hudson and Cairns (2014) state," social presence is a concept built around the evidence of other humans within a virtual environment, with even simple cues such as the score of other players in a computer game being enough to increase social presence."

Social presence awareness is a multidimensional concept (Biocca et al., 2003; Hudson & Cairns, 2014; Shen et al., 2009), based on the evidence of other humans and build upon different Information Technology (IT) artifacts that bring the sense of social presence in different ways (Shen et al., 2009). According to Schroeder (2002), mutual awareness, common focus of attention, and collaborative task performance, are all key elements of social presence. Although definitions of social presence vary, they cluster around these key elements.

While there is still considerable disagreement among authors on what social presence precisely entails, in the present paper we refer social presence awareness as the relevance of users when they are participating in a collaborative activity (Montané-Jiménez et al., 2015).

2.2. Awareness visualization techniques and mechanisms

When working in collaborative environments, team members need to deal with different stimuli at the same time, keeping a record of a large amount of information in the environment (e.g., chat track record or records of versions of documents being collaboratively written). Awareness tools can help users receive the required information to collaborate effectively in Computer Supported Cooperative Work (CSCW) environments. A strategy to display this information and facilitate its interpretation is visualization (Janssen et al., 2011).

Visualization refers to the visual representation and presentation of data to facilitate information understanding (Kirk, 2019). There are many visualization techniques used to represent data that vary by position, size, shape, texture, color, transparency, and orientation. These properties, known as visual variables, differentiate the techniques from each other and have certain characteristics that can be interpreted according to the meaning of the object (Storey et al., 2005). For example, in the course of writing a collaborative text, the color of one part of the text can be interpreted as the authorship of the individual identified with that color, or in a videogame, the color associated with an individual helps to identify him/her as a member of a specific team.

Given the wide array of information visualization techniques, designers must address the critical question of how to convert data into a form that people can easily understand without losing valuable information in the process (Ware, 2012). The selected visual structure should preserve the data and transmit the information effectively, consequently, a graphic is more useful if it is easier to interpret or its interpretation produces fewer errors (Schneiderman, 1999).

According to the perspective of the Human Centered Visualization, the designer must understand the characteristics of the target users, the users' awareness needs, and identify which awareness information is relevant, how it will be obtained, where and how to display the awareness information in a groupware interface. To prevent interruptions during the collaborative activity, it is necessary to carefully balance the need to provide information so the attention required for collaborating is not disrupted. The supply of information in a structured, filtered and summarized manner can provide this balance (Fuks et al., 2005).

After the information that is meaningful to users has been understood and selected, the subsequent step is to analyze how it can be represented and distributed. To select the right media, we must take into account the characteristics of the users, their context, the GS technology to be used, the activity and the team dynamics (Cepero et al., 2018). For example, the user's level of knowledge and experience has effect on interpretation, since the prior knowledge is used to analyze and interpret the awareness visualization (Sacha et al., 2016). An adequate technique selection to implement awareness elements helps to prevent information overload and misinterpretation of data (Gerosa et al., 2003).

In the context of CSCW, some research explored the use of visualization to support awareness in collaborative activities. Gutwin and Greenberg (2002) examined the awareness of the shared workspace, understood as the acquaintance of the collaborators' interactions with the workspace, and proposed a framework for supporting this kind of awareness in small or medium-sized groups working collaboratively. This framework defines the elements that are part of the workspace awareness, the representative mechanisms used to provide different information about the workspace, their uses and examples of how to implement the framework to design of groupware interfaces. According to Gutwin and Greenberg (2002), the awareness information must be perceived and the recipient needs to understand the information. Thus they recommend presenting the information in a direct and familiar way to help users to easily interpret it.

Wang et al. (2007) analyzed the different awareness techniques used in groupware systems and research prototypes, as well as the configuration of their notifications. Idrus et al. (2010) analyzed the use of four visualization techniques (text, 2 D graphics, 3 D avatars, and audio-video) to support different forms of awareness. Herrera et al. (2013) compared awareness mechanisms in different collaborative systems, and propose a taxonomy of such mechanisms. Storey et al. (2005) proposed a framework on the use of visualization to support activity awareness in software development.

In video games context, Nova (2002) reviewed the awareness mechanisms used in video games to support team play and collaboration. This study analyzed FPS (first-person shooter) video games, game guides, and interviews with players to gather information on awareness mechanisms. Most of the interviewed players acknowledge that collaboration is a key factor in winning, that collaboration is not sufficiently developed among participants, and that there are not enough awareness tools. The review of awareness mechanisms shows that some tools were indirectly supporting awareness with maps and lists. There were other tools supporting awareness through visual information that provide clues or signals which imitate the real world, for example blood marks that serve as action indicators, and communication tools like chat which make team member coordination easier (see Figure 1).

Figure 1. Awareness support elements in a FPS videogame (AssaultCube, 2019).

Table 1. Awareness visualization mechanisms in Groupware Systems.

	Workspace awareness				Situation awareness		Social awareness		
Mechanism	Presence	Authorship	Location	Activity	Status	Communication	Emotion	Performance	Reference
Action indicators				✓					Gutwin and Greenberg (2002)
Artefact movement				✓					Nova (2002)
Avatar	✓								Gutwin and Greenberg (2002)
Chat				✓		✓	✓		Nova (2002)
Color (icon or text)		✓							Gutwin and Greenberg (2002)
									Herrera et al. (2013)
Creation colouring		✓							
CPU message					✓				Nova (2002)
Graphic				✓					Wang et al. (2007)
									Herrera et al. (2013)
List				✓					Nova (2002)
Log		✓		✓	✓	✓			Nova (2002)
Map or radar	✓		✓						Nova (2002)
Marking artifacts				✓					Gutwin and Greenberg (2002)
Messages and emails						✓			Herrera et al. (2013)
Participant list	✓								Gutwin and Greenberg (2002)
Participant picture	✓								Gutwin and Greenberg (2002)
Table								✓	Nova (2002)
Tag	✓		✓		✓				Nova (2002)
Telepointer	✓	✓	✓						Gutwin and Greenberg (2002)
Text		✓	✓		✓		✓		Storey et al. (2005)
									Idrus et al. (2010)
Timeline				✓					Wang et al. (2007)
									Herrera et al. (2013)
								✓	Isaacs et al. (2014)

As the result of the literature analysis, Table 1 introduces a series of visualization mechanisms that some researchers in the CSCW area have proposed to support awareness in collaborative activities. As the table shows, the awareness tools discussed in the literature are used to support workspace awareness, situation awareness, and social awareness. Workspace awareness refers to the knowledge that helps users raise awareness of who is present in the workspace (presence), who is responsible for the actions (authorship), where they are working (location) and what actions they are undertaking (activity) (Gutwin & Greenberg, 2002). Meanwhile, situation awareness is one of the most general types of awareness, it refers to the knowledge required to operate a system, and to the perception of the environment's relevant elements (Herrera et al., 2013) that help develop a sense of what is happening. Social awareness refers to the awareness of the social situation of a team member. It includes the other team members' activities and roles, or the way they contribute to a task (performance), and their emotional status (Antunes et al., 2014).

The analysis of the mechanisms used to provide awareness information in GS reveals that attempts to explore and display performance information to users have been limited. Notably, social presence awareness is not addressed in most frameworks, taxonomies, and studies of the mechanisms for awareness support that have been examined. As Table 1 shows, the awareness information presented on collaborators' contributions is presented in the form of either horizontal list as a timeline or vertical list as a table. These reporting modes require the user to conduct a laborious analysis of his or her contributions relative to teamwork in order to evaluate how much he or she has contributed to the teamwork. Therefore, it is important to explore mechanisms for the visualization of this type of awareness to facilitate the interpretation of the performance.

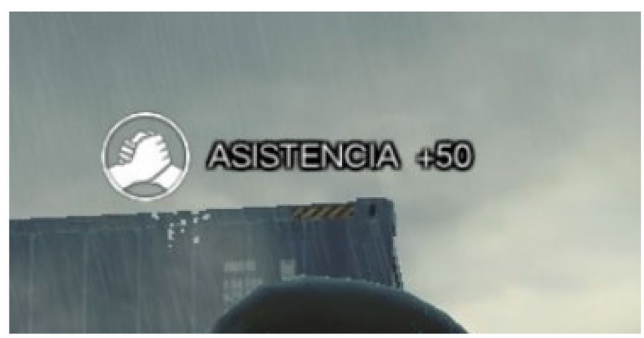

Figure 2. Icon and text.

Looking back at Gutwin and Greenberg (2002), it is crucial to know the user and his context in order to identify how the information is transmitted. So, people can keep using these familiar mechanisms or others that are specific to particular situations and domains. Accordingly, we analized the mechanisms of social presence awareness in competitive collaborative video games. The video game analysis indicates that the most common techniques for visualizing performance information during collaborative activities are text, sometimes together with an icon (see Figure 2, and a bar chart with the player's name, see Figure 3). Also, once the games are over, performance information -known as statistics or scoreboard- is regularly displayed in lists (see Figure 4). It is worth mentioning that some players find tools that help them to learn about their performance. These tools usually display the information as a number and percentage along with bar charts, radial charts, or line charts as in Figure 5.

Performance evaluation is an essential element in games. Many collaborative video games already consider measuring the users' performance and providing visualization mechanisms that support awareness. However, these measurements are often limited to metrics such as scores or levels, which do not include detailed achievements (Montané-Jiménez et al., 2013). An analysis of awareness tools that provide performance information on current video games suggests that new ways of evaluating and presenting player performance are being integrated, metrics such as assists, that count the harm caused to enemies, and KDA, a metric that includes Kills, Deaths, and Assists. While the Assists and KDA are a major step forward in supporting social presence awareness as they include contributions that cause harm to the enemies in battle games, these metrics are an incomplete solution. In fact, evaluating an individual's overall performance requires analyzing this information along with their other contributions.

The outcomes from the analysis of visualization mechanisms that support performance awareness present a framework for selecting visualization techniques appropriate for visualizing social presence. The elements observed in this study give an overview of the visualization techniques that could be appropriate to represent awareness information in the context of collaborative videogames.

3 Social presence visualization system

The social presence visualization system collects social presence data from a groupware system, processes it, and transforms it into a representation that is updated in real-time (see Figure 6). A conceptual architecture for the social presence visualization system in groupware systems is proposed. The conceptual architecture seeks to build a visualization system to generate visual representations of the social presence that can be customized. Figure 7 shows the design of the conceptual architecture.

The conceptual architecture (see Figure 7) includes three components: an extended groupware that generates collaborative activity data, a visualization system that transforms the data into visual representations, and a user who perceives the visualization. The extended groupware contains a social presence sensor that assesses—through

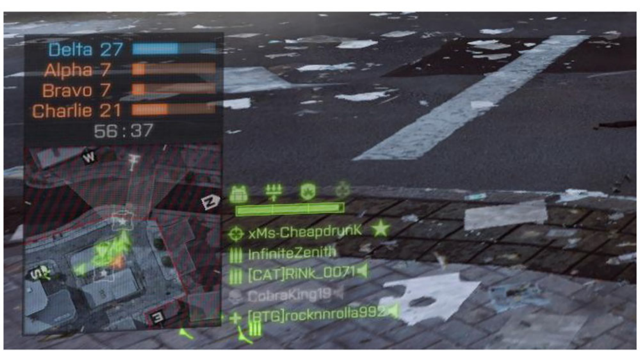

Figure 3. Bar chart.

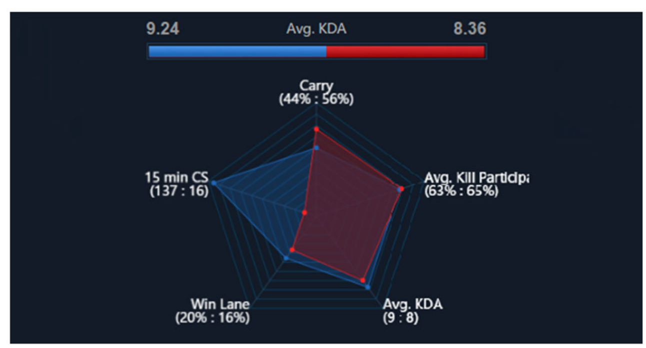

Figure 5. Radial charts.

Figure 4. List.

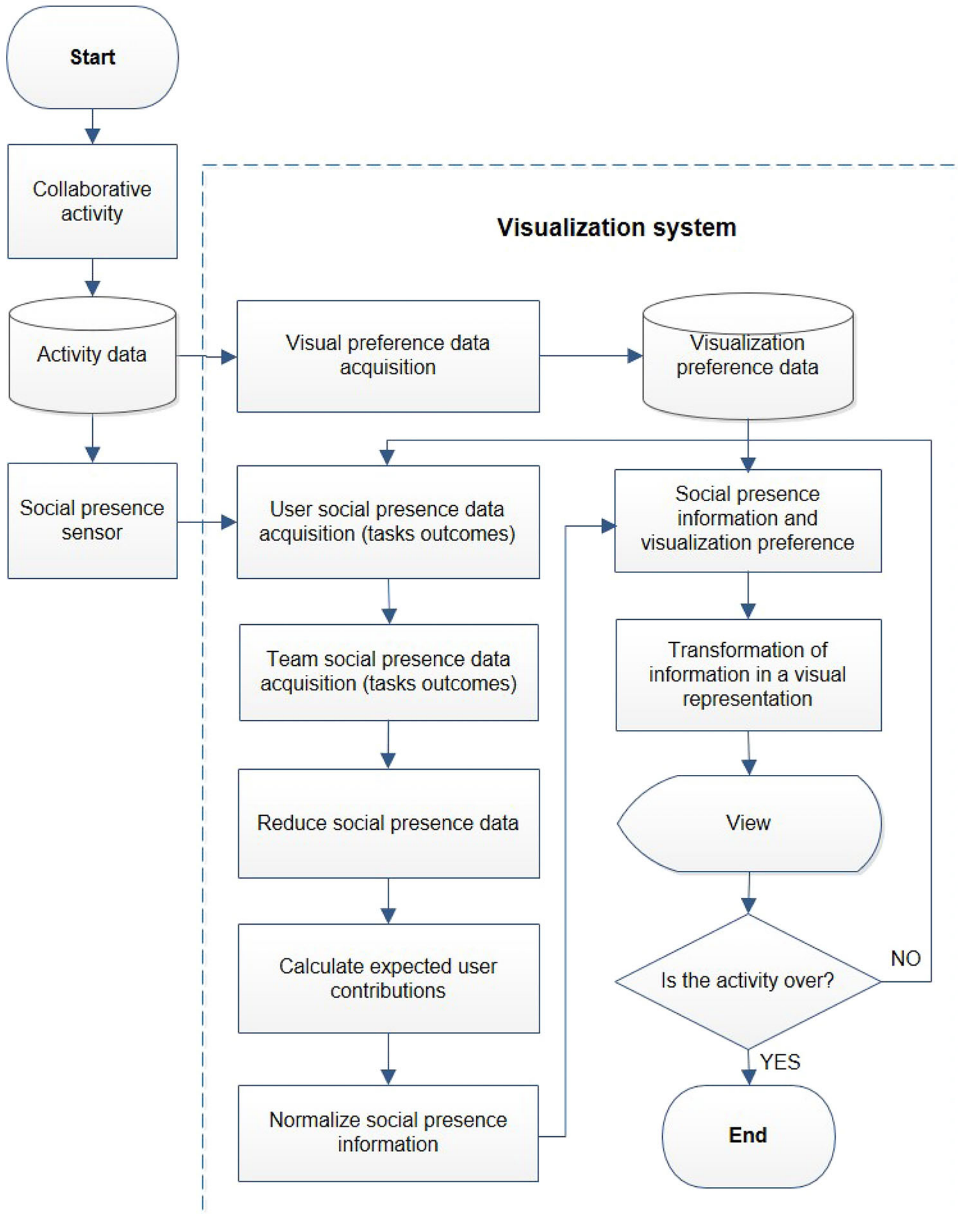

Figure 6. Social presence visualization system.

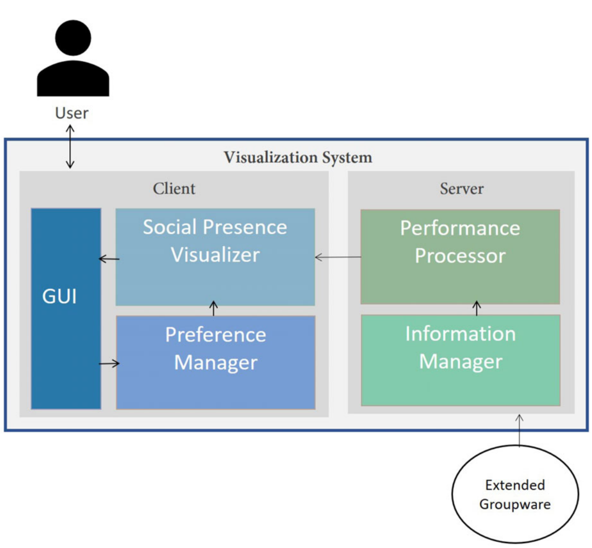

Figure 7. Conceptual architecture of the visualization system.

Table 2. Example of social sensor data.

				Goals			Tasks		
Id	Game	Team	User	+	−	I	+	−	I
1	1	Blue	u_1	14	0	10	18	5	25
2	1	Blue	u_2	19	0	14	34	3	25
3	1	Blue	u_3	27	0	6	18	3	20

Algorithm 1—the objectives and tasks to measure social presence. Once the sensor analyzes the data for each collaborator's contributions and calculates their social presence, a six-integer array that represents the social presence of each user is stored in a database (see an example in Table 2). Subsequently, the visualization system gathers social presence data and processes it.

Algorithm 1. Algorithm for the measurement of social presence Montané-Jiménez et al. (2015).

Require: *space*, *actor*, t is *time*, W_e is the array or weighting vector, Activity elements $E\ [e_1, e_2, \ldots, e_n])$ where E are the tasks' outcomes
Ensure: *f SocialPresence* of *actor*

$e_{index} \leftarrow 1$
$SW_e \leftarrow array[1, 2, \ldots, length(E)]$
for all $e \in E$ **do**
  $w_e \leftarrow WeightingoftheElement(e, W_e)$
  $te_c \leftarrow AddTeamElements(space, e, t)$
  $te_a \leftarrow AddActorsElements(space, actor, e, t)$
  if $te_c > 0$ **then**
    $g_e \leftarrow (te_a \times 10)/te_c$
  else
    $g_e \leftarrow 0$
  end if
  $e_{wa} \leftarrow g_e \times w_e$
  $SW_e[e_{index} + +] \leftarrow e_{wa}$
end for
$f\ SocialPresence \leftarrow \left[\sum_{i=1}^{e_{index-1}} SW_e\right]$
return *f SocialPresence*

The suggested visualization system consists of four elements: information manager, performance processor, preference manager, and social presence visualizer. The information manager gathers the stored social presence data and sends the information to the performance processor. The performance processor element processes and normalizes the data, adjusting the measured values to a 0 to 1 scale in order to obtain uniform measurements that are easy to compare and understand in relation to the scale.

3.1. Information manager

The information manager collects social presence information from the extended groupware. Social presence information is gathered in an array of six integers that represent each player's social presence (see Figure 8). These values reflect the overall results of the achieved objectives (positive, negative, and neutral) and completed tasks (positive, negative, and neutral). Since the objectives are task-based, the results of the objectives and tasks reflect the same information at different levels of abstraction. This research will use task information as a social presence indicator because these data reflect the same contribution as the target data but in more detail.

3.2. Performance processor

The performance processor reduces the data obtained from the social presence sensor. This element is designed to acquire and reduce the array of data that represents social presence at an individual and team level. These are the parameters received: the actors of the collaborative activity; the team identifier; the time (t) in seconds up to where the

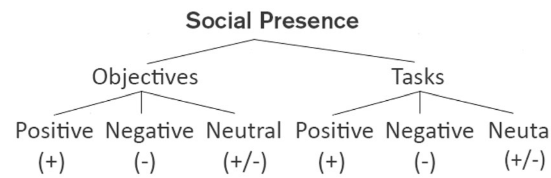

Figure 8. Social presence representation (Montané-Jiménez et al., 2015).

social presence is calculated; and the elements of the social presence retrieved from the Social Presence Sensor, where E is the array of the positive, negative, and neutral elements of an actor's social presence during the collaborative activity in the space of time t. The values of these elements are used to calculate a unique social presence value using the *reducePresence* function. Through this function the value of the element that represents a negative impact is subtracted from the element that represents the positive impact to the team work. It is important to note that the proposed function to reduce social presence does not include the neutral values of the social presence outcomes because these represent tasks that do not contribute to the social presence of the team. For example, in AssaultCube-CX these tasks could be changing weapons or looking at a map which are necessary for the progression of the game but are not relevant in terms of social presence. In the case of the team's social presence, as well as in the individual representation of social presence, an array of three numbers represent the sum of the positive, negative, and neutral elements of all the team members' social presence. In addition, the *reducePresence* algorithm is used to obtain a unique value that represents the team's social presence.

To normalize social presence data, it is necessary to calculate the expected contribution per actor. The *ExpectedContribution* function takes the size of the *Actor* array and assigns the result to N_a. This function calculates the expected contribution per actor by dividing 1 between the number of actors (N_a), shown in Equation (1).

$$ExpectedContribution = \frac{1}{N_a} \tag{1}$$

The function to normalize the social presence data receives these values: the actors in the collaborative activity, their *ExpectedContribution*, the Social Presence of the team SP_t, and the actor's Social Presence SP_a. These values are used as input parameters by the function to normalize the Social Presence of an actor through dividing the SP_a value between the product of the multiplication of SP_t by *ExpectedContribution* (see Equation (2)). The outcome of this function is the value of the normal social presence of an actor or user (SP_n), with 1 being the desired value that represents an equitable collaborative activity; a value above" 1" means that the performance is above target; and a value below 1 means that the contributor is not meeting its target.

$$SP_n = \frac{SP_a}{SP_t \cdot ExpectedContribution} \tag{2}$$

3.3. Preference manager

The preference manager, as the name suggests, collects the user's visual preference. The preference manager collects information on the preference of the level of detail of the social presence (individual or team) and the preferred visual representation. In general, the use of familiar and easy-to-interpret visual representations is recommended. For example, in video games, using a bar graph or an icon accompanied by the value of the performance indicator is common.

3.4. Social presence visualizer

The social presence visualizer transforms the social presence information into the user's selected visual abstraction, and the user perceives it through the graphical interface (GUI). Figure 6 presents the details of the proposed social presence visualization system functioning.

4. Case study

The social presence literature review prompted the use of the social presence sensor developed by Montané (Montané-Jiménez, 2016; Montané-Jiménez et al., 2015) as a tool to gather social presence data. The social presence information obtained from the sensor was used to create a social presence awareness visualization system in a videogame.

AssaultCube-CX is used as a case study to describe how the visualization system works in a collaborative videogame. AssaultCube-CX is the extended version of AssaultCube (AssaultCube, 2014; open source first-person shooter videogame), which provides data at a low level of the game activity that enables the study of how people interact through tasks and contributions. This tool allows us to analyze user interactions, which can be analyzed to measure social presence. Then, the social presence visualization system is explained with the battle activity in *Team keep the flag* mode as a scenario.

Social presence awareness information is the relevance of users when they are participating in a collaborative activity. In this case study, the videogame AssaultCube-CX, based on CAMUS model (Montané-Jiménez, 2016), regards the tasks performed, the objectives achieved, and the goals accomplished as the elements with the greatest impact on the players' collaboration. According to the model of the collaborative activity performed in AssaultCube-CX (in its *Team keep the flag* mode) developed by (Montané-Jiménez et al., 2015), the goal is to win the battle. The objectives could be to destroy the enemy or capture the flag, and the tasks are walking, shooting, changing weapons, keeping the flag, and sending a message (Montané-Jiménez et al., 2015). Throughout a game, every second of the game generates data of these elements per participant. These low-level data are subsequently processed by a social presence sensor through Algorithm 1 (Montané-Jiménez et al., 2015). Table 2 presents an example of the data from the social sensor that could be obtained in the AssaultCube-CX video game scenario.

Table 3. Example of normalization results.

	fSP_t			fSP_a					
User	+	−	I	+	−	I	SP_t	SP_a	SP_n
u_1				18	5	25		13	0.6
u_2	70	11	70	34	3	25	59	31	1.6
u_3				18	3	20		15	0.8

Once the sensor analyzes the collaborative activity, an array of six integers that represent the players' social presence is obtained. These values correspond to the overall outcomes of the achievement of objectives and tasks. For example, in the previous scenario (see Table 2), u_1 social presence is an array of six numbers that reflect the performed objectives and tasks. The numbers that reflect u_1 contributions according to the objectives reached are the following: 14 positive points resulting from the achievement of objectives such as knocking down enemies and keeping the flag; 0 negative points means that the player did not achieve objectives that could affect his team, for example knocking down a teammate; and 10 neutral points are the result of completing objectives that do not affect or benefit his team. Table 2 shows the contributions in terms of tasks carried out. The u_1 obtained 18 positive points as a result of effective shots to enemies and enemies holding a flag, 5 negative points reflecting the impact on the team by effectively shooting a teammate, and 25 neutral points as a result of tasks such as changing the weapon and failed shots.

When actor u_1 connects to the GS and performs a task such as shooting an enemy, the performance processor reads the social presence measure stored in the database and obtains the cumulative full social presence of u_1 (fSP_a). To obtain the social presence of the team (fSP_t), the performance processor adds the outcomes of the social presence of all the team members (u_1, u_2 and u_3), thus obtaining an array of three numbers that represent the total of the positive (+), negative (−) and neutral (—) contributions. The performance processor uses the generated fSP_t and fSP_a arrays to reduce social presence with the *reducePresence* function. As Table 3 shows, this function adds the positive (70) and negative (−11) values of the fSP_t to obtain the value of the team's social presence SP_t (59). The *reducePresence* function is used to calculate the social presence of u_1 by adding the positive and negative values (18 and −5); the result of u_1's social presence is 13.

We used Equations (1) and (2) to normalize the social presence data of u_1. As Table 3 shows, u_1 had a social presence (SP_a) of 13, which translated to a normalized value is equivalent to 0.6, thus meaning that the contributions of actor u_1 were lower than expected. Table 3 shows that the normal social presence of u_1 (SP_n) was the lowest of all the team members. It also shows that the normal social presence of the actor u_2 was the highest (even greater than 1), thus meaning that u_2 compensated for the low performance of u_1, making greater contributions than expected. In an ideal scenario, where all actors work equitably, the normal social presence of users would be a value close to one.

These processes are performed when the Visualizer requests them. The visualization system performance processor retrieves the social presence sensor data stored in the database and reduces them to a single social presence value. The performance processor also normalizes the social presence data and sends the result to the visualizer for a graphical representation consistent with the user's visualization preference.

5. Social presence visualizer prototype

The prototype of social presence visualization system (VIPSO) was built as a Web application, since it establishes a design framework through Web services for the integration of independent collaborative videogames that are accessed through services on the web. The design and development of the social presence visualization system were built around a user-centered design approach (Standard, 2010). This is an iterative approach based on the analysis of users and their context for the development of a design proposal.

User-centered design relies on the identification of future users of the system and on the understanding of the context of use to specify user requirements, to propose a design solution, and to evaluate the design. From studies of the characteristics, habits and uses of videogames (ADESE, 2006; Aguilar, 2008; Jansz & Tanis, 2007; Montag et al., 2011) it is possible to depict the profile of a typical player as a young individual (aged between 12 and 50 years) with knowledge and experience in the use of computers and Internet. The target population for the AssaultCube-CX case study is limited to PC players, i.e., users who use a laptop or desktop computer as a device to play videogames. Note that in the AssaultCube-CX game, in addition to the computer, players need a keyboard and mouse to play and possibly a headset to communicate with their peers remotely. In addition to these devices, a monitor is indispensable to observe the game. When it comes to the use of these devices, Tran (2006) points out that users use both hands to play: the main hand (right for right-handed players or left for left-handed) to control the mouse and the other hand to operate the keyboard. Furthermore, regarding the system environment, ADESE (2006) reports that most players play at home or at friends' homes.

After analyzing the characteristics of VIPSO users and the visualization system usage context, we identified the following functional and non-functional requirements for a social presence visualization system:

Functional requirements

- To identify each team member
- To be able to analyze the game collaborative activity
- To be able to process the social presence of all collaborators simultaneously
- To display the individual social presence graphically
- To display the team social presence graphically
- To keep social presence up to date

Non-functional requirements

- To be user-friendly and intuitive
- To be easy to use and learn

Figure 9. Representation of social presence through a bar chart.

Figure 10. Representation of social presence through a bar pictogram.

- To be interactive and versatile
- To be flexible to different monitor sizes
- To contain a definition of social presence

Awareness information is often displayed on the monitor where the collaborative activity takes place, hindering the user's main task (Truemper et al., 2008). In light of this problem, awareness social presence information will be displayed on a secondary or peripheral screen that facilitates the search of information. When displaying the information on the peripheral of the system, the secondary screen reduces the users' cognitive load because they can verify the information at a glance (Truemper et al., 2008).

Upon the recommendations regarding the design of human-centered visualization tools in (Sedig et al., 2014), we included interactive functions into the system that provide users with the ability to adjust the visualizations to their needs and preferences. These functions are: the option *select individual or team view* which allows the user to choose between viewing their own individual performance or all team members' performance. Likewise, the option *select visualization technique* provides different visualization options to represent social presence, letting users decide which one to use.

We followed Gutwin's recommendations for presenting awareness information. Gutwin and Greenberg (2002) recommend presenting awareness information in ways that are simple and familiar to people to make it easier to interpret. Therefore, we selected visualization techniques identified in the literature review that are familiar to videogame users to facilitate interpretation: the bar graph where the length of the bar represents performance (see Figure 9); the pictogram to represent social presence through color (see Figure 10), where green represents optimal social presence and red represents poor participation; the donut chart with the percentage that it represents (see Figure 11). Finally, the radial graph (see Figure 12) was also selected to represent team social presence, where the distance from each edge represents the performance of each collaborator and the polygon area represents the team's social presence.

Once the context of the social presence visualization system in a collaborative videogame was analyzed and the user requirements were defined, we developed a proposal for a social presence visualizer (VIPSO). As Figure 13, shows, the VIPSO prototype was assessed in terms of usability in four iterations that facilitated the identification of opportunity areas and the adjustment to the users' needs to finally reach a design solution.

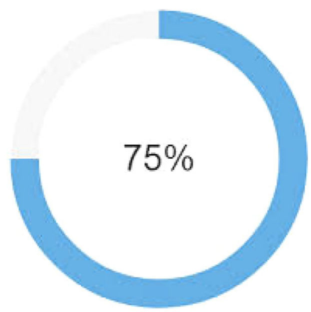

Figure 11. Representation of social presence through a donut chart.

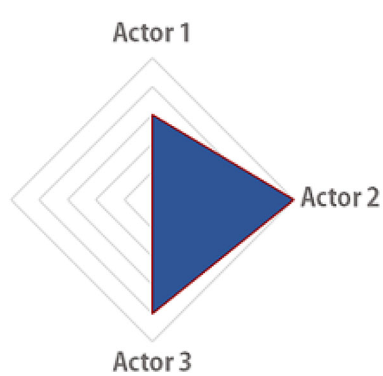

Figure 12. Representation of social presence through a radial chart.

At the beginning of the user-centered design process, we develop a low-fidelity prototype (Mockup). It was assessed with six collaborative videogame users using a *quick and dirty* usability test. This test resulted in evidence that the proposed visualization techniques (pictogram, bar graph, donut chart, and radial) are easy to interpret and suitable to show social presence information to collaborative videogame users. The test results also indicated that users were either unacquainted with the meaning of social presence information or interpreted it differently.

After the first iteration, the option *about* social presence was added to the design and a prototype was implemented. In this second iteration, two design proposals were developed and assessed with the same visualization and iconography techniques but differently arranged in the interface. Six users participated in a comparative test using the prototypes and evaluated perceived satisfaction of the two interfaces of the VIPSO social presence visualizer. We selected the VIPSO interface design perceived with greater satisfaction according to the feedback from the users. We added a function to consult the social presence track record during this phase.

In the third iteration, after the required adjustments to the VIPSO design were made, a group of six usability experts conducted a heuristic evaluation to verify the compliance of VIPSO with respect to the heuristics for the evaluation of a peripheral visualization system (Mankoff et al., 2003). The heuristic evaluation findings demonstrated that VIPSO fully or partially complies with the heuristic principles applicable to peripheral environments. However,

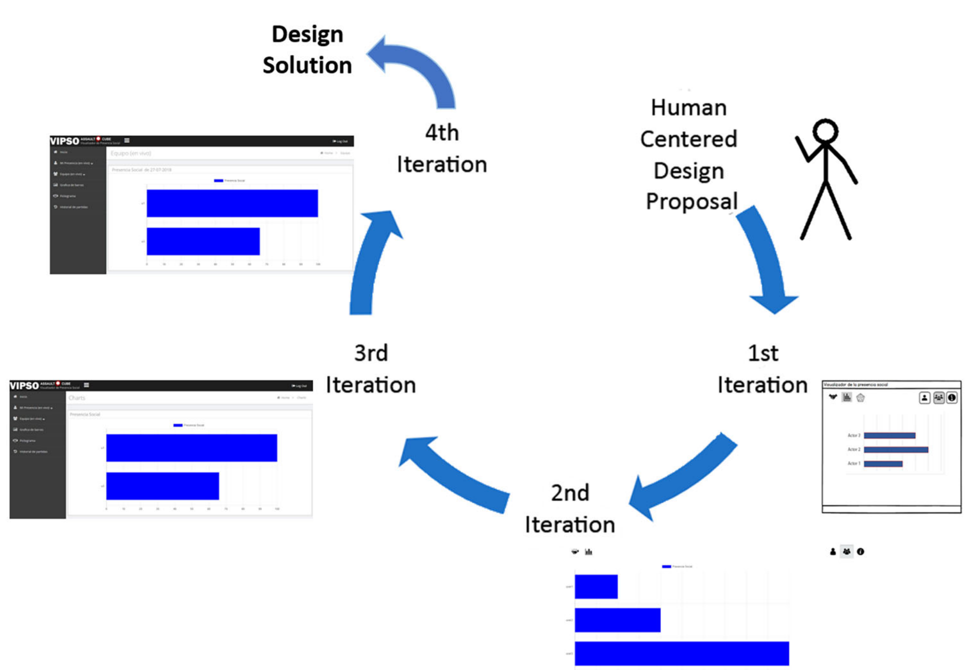

Figure 13. Design process and development of the social presence visualizer.

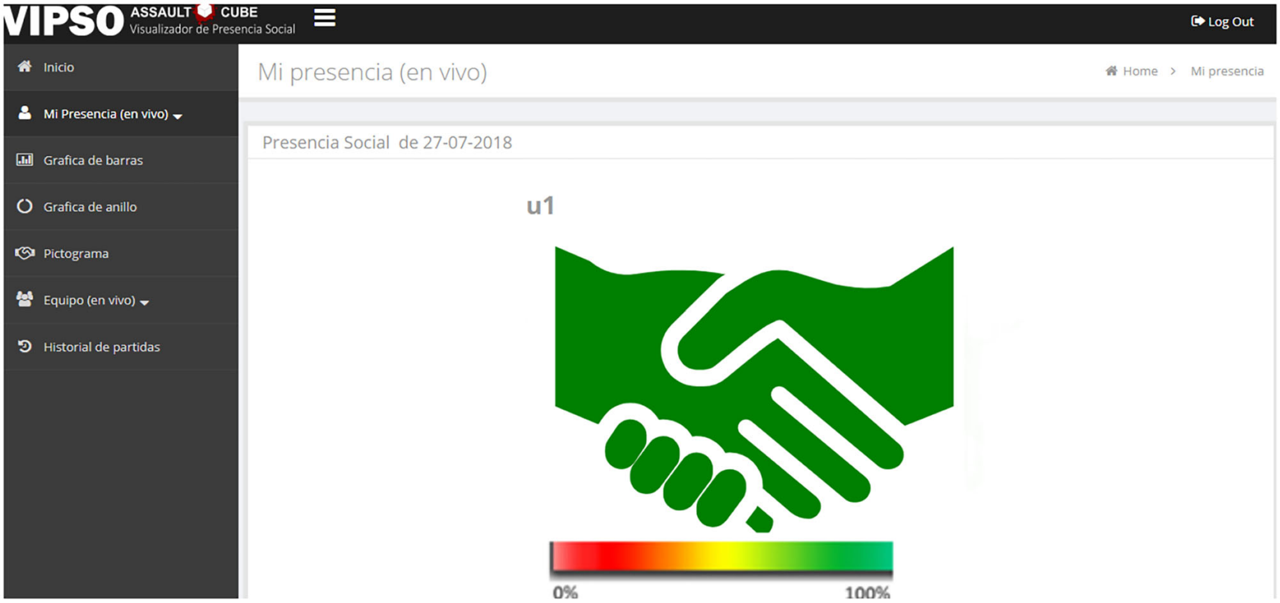

Figure 14. Individual display interface.

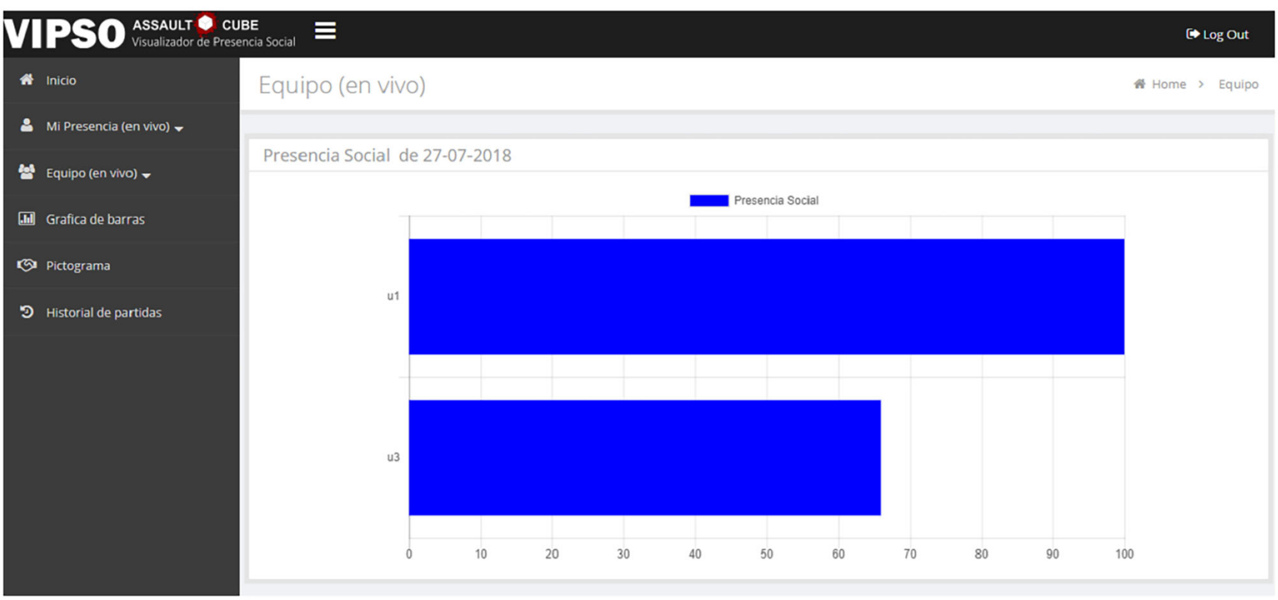

Figure 15. Team display interface.

it was recommended to add animated *gifs* to inform users about the state of the system and alert messages when social presence remains low for a certain period of time.

Finally, in the fourth iteration, following the experts' recommendations, we included an animated load *gif* to notify users when data is being loaded, and we also added an alert message to encourage users to participate when they maintain a low social presence. Figures 14–16 show the interface of the final version of the individual VIPSO display, the team display, and the game track record.

VIPSO was designed to retrieve data from AssaultCube-CX collaborative activity, to process social presence, and to visually display results. For this purpose players need to identify themselves with a (*username*) through the VIPSO login window. Once logged in into the system, VIPSO displays four main screens: Home, My Presence (Live), Team (Live) and Game track record. The home screen (see Figure 17) provides a brief description of VIPSO and a definition of social presence. The My Presence screen (see Figure 14) loads the social presence of the user's in the most recent game and the social presence is presented according to the selected method. The Team screen or display (see Figure 15) shows the social presence of all team members in the current or most recent game. Finally, on the Game track record screen (see Figure 16) the social presence record of past games is depicted through a line graph. In addition to the visual representation of the social presence, VIPSO has a *mouseover* function that highlights the performance with a number when the cursor is passed over the graph.

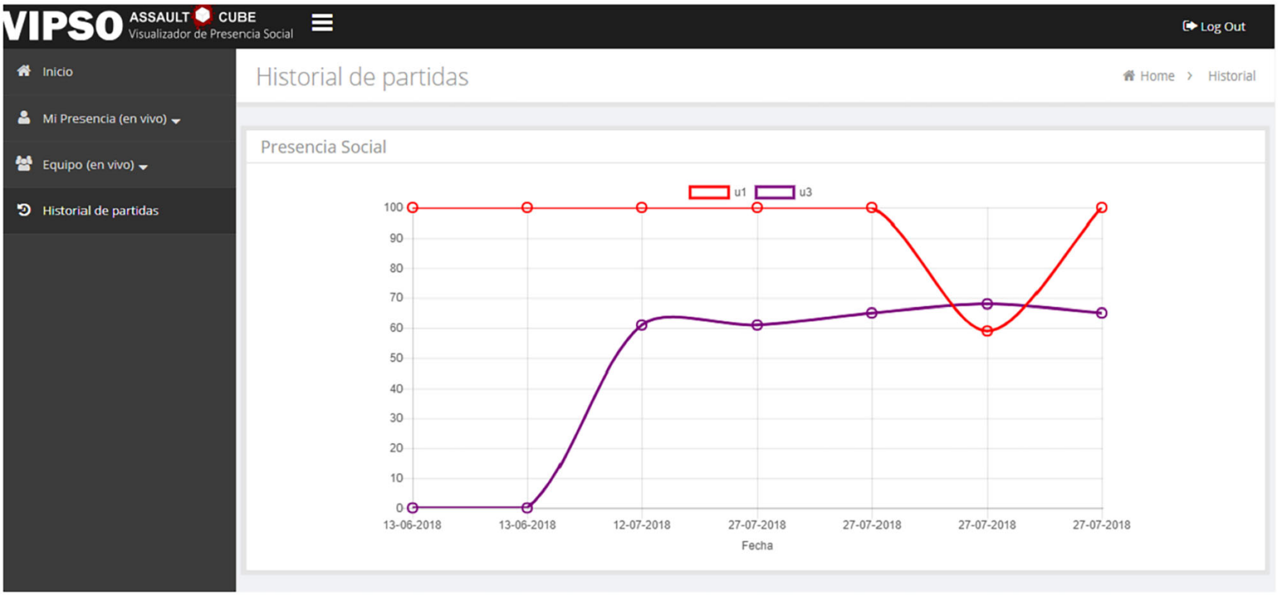

Figure 16. Game track record.

Figure 17. Home.

The proposed social presence visualization system interacts with a collaborative videogame, analyzes the collaborative activity, and presents the social presence information graphically. The visualization system relies on the proposed conceptual architecture, which includes two modules: the extended groupware core and the visualization system. For the purpose of this case study, the collaborative videogame AssaultCube-CX was taken as an extended groupware and the visualization system was developed using web technology. A user-centered approach was adopted for the design and development of the Social Presence Visualizer (VIPSO).

6. Experimental assessment

This experiment aims to evaluate the effects of social presence visualization on team performance in a collaborative videogame. In this study, an experiment was designed to evaluate the users' social presence while they were playing the AssaultCube-CX videogame in a *Team keep the flag* mode. To this end, the performance in terms of users' social presence was measured while they were playing an AssaultCube-CX with and without the VIPSO visualizer, in order to evaluate the effect of social presence visualization on teamwork.

To recruit participants, we made a call via social networks (Facebook) to invite players to participate in this research. In addition to the social media calls, posters were placed in computer centers for PC gamers, computer equipment stores, and at the Faculty of software engineering of the Universidad Veracruzana.

The study was conducted throughout December 2019 in an experimental classroom of the Master in User-Centered Interactive Systems at the Universidad Veracruzana. Each user had a laptop and a monitor during the test. The laptop screen was used as the main monitor to play AssaultCube-CX in the usual way, and the secondary monitor was used to display social presence awareness information through VIPSO.

This experiment consisted of a series of tests with 12 volunteer videogame players from Mexico aged between 18 and 36 (with different levels of experience, from beginner to expert players). All the volunteers who participated in the tests were men. The process of evaluating social presence took place in two stages: in the first stage, a test to measure social presence was carried out without the visualization mechanism; in the second stage, the users' performance was measured through the presentation of the visualizer. While running the tests, AssaultCube-CX recorded all the actions that players performed, for example, the number of enemies knocked down, the number of teammates knocked down, the number of flag captures, among others. The data recorded during the game captured the details of the activity and made it possible to calculate the users' social presence. The procedure for this test is explained below:

- **Opening**. At this stage, the participants are acknowledged for their participation and introduced to the people who will conduct the test. After a brief explanation of the procedure and the purpose of the test, a letter of consent is explained to the participants and they are asked to sign it.
- **Game session (without VIPSO)**. The type of game and a briefing about the basic functions of the video game are provided. Thereafter they had 10 min to explore the game options and 15 min to play a game.
- **Game session (with VIPSO)**. Players learn about the game type and the visualization mechanism. Participants logged in into VIPSO and consulted their social presence while playing an AssaultCube-CX game. They had 5 min to become familiar with the visualization system and 15 min for the development of the Team keep the flag activity.
- **Discussion about the game experience**. Participants answer the Computer Systems Usability Questionnaire (CSUQ) to measure users' perceived satisfaction with VIPSO usability.
- **Closure**. Users are acknowledged for their participation.

In order to avoid any differences in the circumstances, the same user groups participated in both tests. However, to prevent potential learning bias that could influence performance, the tests (with and without VIPSO) were interleaved in each session. For example, the first team started playing AssaultCube-CX without VIPSO followed by another VIPSO-supported videogame, the second team first played with VIPSO and then with only the videogame. In total there were 6 games (3 with and 3 without VIPSO). Four players participated in each game.

7. Results

We conducted an experiment with the participation of 12 volunteer videogame players to evaluate the effects of social presence visualization. To assess social presence it was necessary to analyze the records for each player, including the number of enemies shot down, the number of teammates shot down, and the number of flag captures. Figure 18 shows the outcomes from the evaluation of social presence in the exploratory experiment.

The graph in Figure 18 shows that social presence during the collaborative activity supported by VIPSO (represented with the orange bar) was maintained or increased in 10 out of the 12 participants with respect to the non-supported social presence awareness information (represented with the blue bar).

In order to know the perceived satisfaction of the VIPSO system, volunteers in this study answered the Computer System Usability Questionnaire (CSUQ version 3). The CSUQ questionnaire consists of 16 questions in form of statements that cover issues related to the usefulness of the system (1, 2, 3, 4, 5 and 6), the quality of the information (7, 8, 9, 10, 11 and 12), the quality of the interface (13, 14 and 15), and the overall satisfaction with the system (16). Users rated each statement using a 7-point Likert scale,

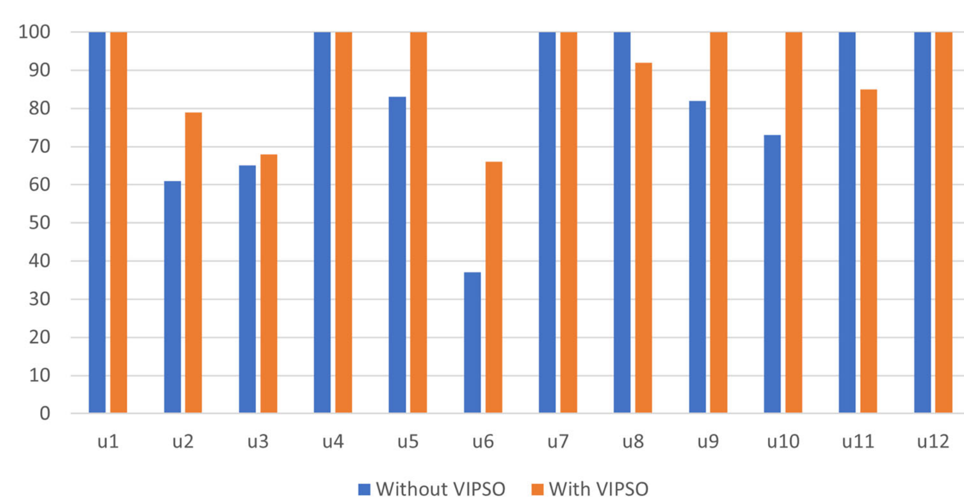

Figure 18. Results of social presence test.

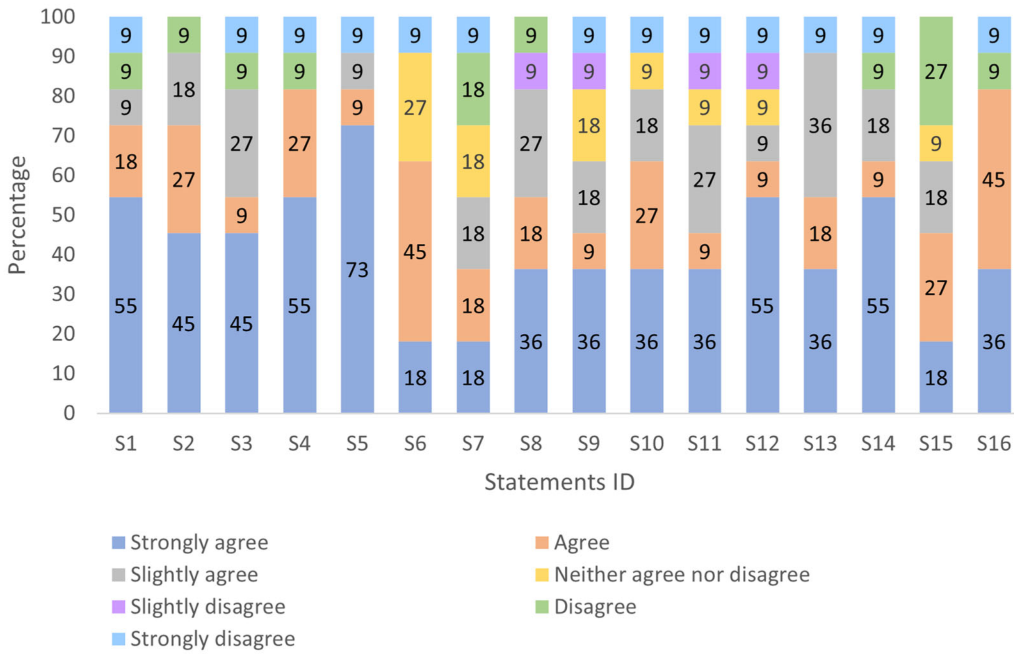

Figure 19. Results of the satisfaction survey.

Table 4. VIPSO satisfaction results by category.

	SYSUSE	INFOQUAL	INTERQUAL	OVERALL
Mean	2.33	2.78	2.66	2.56
Lowest	1.16	1.00	1.00	1.31
Highest	6.66	6.50	6.66	6.50
Standard deviation	1.62	1.68	2.34	1.57

where 1 meant" strongly agree" and 7 meant" strongly disagree." Figure 19 shows the results of the survey as part of the experiment on users' perceived satisfaction with the VIPSO system.

Figure 19 shows the result of VIPSO's perceived satisfaction. VIPSO users expressed high satisfaction on the system's usefulness, and between high satisfaction and satisfaction on the quality of the information and the quality of the interface. Finally, regarding the overall satisfaction of the system, users expressed a favorable opinion in regard to the overall satisfaction of the system. Table 4 shows the mean, the lowest value, the highest value, and standard deviation obtained by category: the score of the utility of the system, the quality of the information, the quality of the interface, and overall satisfaction.

Analyzing the Table 4 and considering that low scores are better than high scores (the best value of the scale is 1) in the CSUQ seven-point scale, the results indicate that the overall satisfaction of VIPSO -which is between 2 and 3 in all its categories- is perceived as good.

8. Discussion

The social presence visualization system represents the performance through a bar chart, donut chart, pictogram or radar diagram, depending on the user's preference. The outcomes from users' observation during this research show no problems interpreting the information presented because it was presented through representations familiar to gamers according to our previous analysis. We also observed that nine participants (75%) used bar graphs to consult their social presence during an AssaultCube-CX game. This gives us clues about the preferred visualization technique for representing social presence in collaborative video games.

In addition to performance information, the visualization system provides messages that encourage user participation when their social presence is low (less than 11%) for 5 min. The participants' high social presence in the exploratory test did not trigger this mechanism. Prior to the experiment, a pilot study was conducted with intermediate and beginner players whose social presence was less than 11% during a game. Therefore, in this test, as opposed to the exploratory experiment, the message "Your teammates need your help, support them" appeared. When the participants read the alert message, they communicated with their peers to better coordinate and support them. For example, one participant explicitly says phrases like: *What can I do for you?*. Thus, from the result of a proactive attitude, communication, and coordination with their peers, users intensified their contributions to teamwork. Although the exploratory study did not show any messages, the participants' social presence heightened when they were aware of their performance. So both tests show that the addition of tools to measure and display performance in terms of social presence fosters the understanding of one's own relevance, which stimulates a better collaboration and support to peers.

In the social presence evaluation study, to avoid bias in the social presence results and perceived satisfaction, we do not include people who had participated during the user-centered design process of the display system. The results of this study indicate that social presence visualization, in terms of team performance, has positive effects on collaborative videogame players. However, given the reduced number of volunteers in the exploratory test, more tests with more users are necessary to study user behavior in other types of collaborative videogames. Therefore, the use of social presence visualizers in other types of collaborative videogames and their possible use in other scenarios or fields of application should be envisaged for future work.

9. Conclusions and future work

This research aimed to examine how to show the social presence information and analyze the effect of social presence visualization on users' performance. The analysis of social presence representations shows that tables and timelines are used in groupware systems to present social presence, while videogames, in addition to tables, display the social presence information through pictograms, gauges, bar charts, and radar charts.

As part of this study, we proposed a social presence visualization system architecture and used it to build a visualization system prototype in a collaborative video game. We designed and developed the social presence visualization system using the user-centered design approach. An iterative design approach that, based on tests throughout the project life cycle, allows learning through empirical evidence and redesigning the product to adapt it to end-users' capabilities, expectations, and aptitudes. After the prototype construction, we examined the effect of social presence awareness visualization on team performance in the AssaultCube-CX videogame.

Our study examines the effects of social presence visualization in a collaborative videogame. We found that 10 out of the 12 participants increased their team performance or maintained it (when already was optimal) with social presence visualization support. The result is consistent with Torres study Torres et al. (2019), which indicates "a trace of a positive effect on users that visualize the team performance indicators." The results of the exploratory test show the usefulness of the visualization system to increase awareness of social presence, encourage collaboration, and support team performance in a collaborative videogame.

The collaborative video game AssaultCube-CX used as a case study, like other collaborative systems, integrates different awareness visualization mechanisms. Like most team games, this video game also has a score-based metric system that measures the achievement of specific targets (regardless of whether they contribute to teamwork). Although these have been useful to support awareness of individual performance, the social presence visualization mechanism by showing performance in terms of team support shows to be effective in encouraging teamwork in a video game. The team performance analysis from composite indicators has also been explored in other fields such as soccer. Other works, such as Gamble Gamble et al. (2019) and Robertson Robertson et al. (2016), analyze the game and team performance variables that contribute to the game's outcome. Gamble Gamble et al. (2019) identified 18 variables that are useful to analyze the outcome of team performance, and that could be combined and transformed into new performance indicators. However, these works focused on the identification of indicators and the information is not displayed.

This study demonstrates that using a social presence visualization system in a collaborative video game can positively influence collaboration between team members. For future work, we propose to modify the visualization system to be more flexible and able to adapt to different scenarios, collaborative activity models (not only video games), and contexts of use to adjust the design and content of the information according to the device used. This goes beyond responsive design, which adapts to different resolutions and screen sizes. The next generation visualization system should also contemplate whether the screen is where the collaborative activity takes place (the shared workspace), or whether it is a secondary monitor or peripheral device to the system.

Disclosure statement

No potential conflict of interest was reported by the author(s).

ORCID

Maria Teresa Cepero http://orcid.org/0000-0002-0255-4256

References

ADESE. (2006). *Estudio de hábitos y usos de los videojuegos 2006* (Tech. Rep.). La Asociacián Española de Videojuegos.

Aguilar, J. A. (2008). Videojuegos. negocio que no es juego. *Revista Del Consumidor*, *89*, 35–43.

Antunes, P., Herskovic, V., Ochoa, S. F., & Pino, J. A. (2014). Reviewing the quality of awareness support in collaborative applications. *Journal of Systems and Software*, *89*, 146–169. https://doi.org/10.1016/j.jss.2013.11.1078

AssaultCube. (2014). *Screenshots*. http://assault.cubers.net/media.html.

AssaultCube. (2019). *AssaultCube's interface*. https://assault.cubers.net/docs/interface.html.

Biocca, F., Harms, C., & Burgoon, J. K. (2003). Toward a more robust theory and measure of social presence: Review and suggested criteria. *Presence: Teleoperators and Virtual Environments*, *12*(5), 456–480. https://doi.org/10.1162/105474603322761270

Cepero, T., Montané-Jiménez, L., Mezura-Godoy, C., & Benítez-Guerrero, E. (2018). Factores para el diseño y vizualización del awareness en sistemas groupware. *Pistas Educativas*, *39*(127).

Dourish, P., & Bellotti, V. (1992). *Awareness and coordination in shared workspaces* [Paper presentation]. Proceedings of the 1992 ACM Conference on Computer-Supported Cooperative Work (pp. 107–114). ACM. https://doi.org/10.1145/143457.143468

Fuks, H., Raposo, A. B., Gerosa, M. A., & Lucena, C. J. (2005). Applying the 3c model to groupware development. *International Journal of Cooperative Information Systems*, *14*(02n03), 299–328. https://doi.org/10.1142/S0218843005001171

Gamble, D., Bradley, J., McCarren, A., & Moyna, N. M. (2019). Team performance indicators which differentiate between winning and losing in elite gaelic football. *International Journal of Performance Analysis in Sport*, *19*(4), 478–490. https://doi.org/10.1080/24748668.2019.1621674

Gerosa, M. A., Fuks, H., & Lucena, C. (2003). Analysis and design of awareness elements in collaborative digital environments: A case study in the aulanet learning environment. *Journal of Interactive Learning Research*, *14*(3), 315–332.

Gutwin, C., & Greenberg, S. (2002). A descriptive framework of workspace awareness for real-time groupware. *Computer Supported*

Cooperative Work (CSCW), *11*(3–4), 411–446. https://doi.org/10.1023/A:1021271517844

Herrera, A., Rodríguez, D., & García Martínez, R. (2013). *Taxonomía de mecanismos de awareness* [Paper presentation]. XVIII Congreso Argentino de Ciencias de la Computación.

Herrera, A., Rodríguez, D., & García-Martínez, R. (2014). Awareness de Modalidades de Interacción para Epacios Vairtuales de Trabajo Colaborativo. In Z. Cataldi & F. J. Lage (Eds.), *Memorias IV Jornadas de Enseñanza de la Ingeniería* (pp. 2313–9056). Universidad Tecnológica Nacional.

Hudson, M., & Cairns, P. (2014). Interrogating social presence in games with experiential vignettes. *Entertainment Computing*, *5*(2), 101–114. https://doi.org/10.1016/j.entcom.2014.01.001

Hudson, M., & Cairns, P. (2016). The effects of winning and losing on social presence in team-based digital games. *Computers in Human Behavior*, *60*(2), 1–12. https://doi.org/10.1016/j.chb.2016.02.001

Idrus, Z., Abidin, Z., Zaleha, S., Hashim, R., & Omar, N. (2010). Awareness in networked collaborative environment: A comparative study on the usage of digital elements. In M. V. Garcia, F. Fernández-Peña, & C. Gordón-Gallegos (Eds.), *Recent advances and applications of computer engineering* (pp. 236–241). Springer.

Isaacs, K. E., Giménez, A., Jusufi, I., Gamblin, T., Bhatele, A., Schulz, M., Hamann, B., & Bremer, P.-T. (2014). *State of the art of performance visualization* [Paper presentation]. Eurographics Conference on Visualization (EuroVis) (2014).

Janssen, J., Erkens, G., & Kirschner, P. A. (2011). Group awareness tools: It's what you do with it that matters. *Computers in Human Behavior*, *27*(3), 1046–1058. https://doi.org/10.1016/j.chb.2010.06.002

Jansz, J., & Tanis, M. (2007). Appeal of playing online first person shooter games. *Cyberpsychology & Behavior*, *10*(1), 133–136. https://doi.org/10.1089/cpb.2006.9981

Kirk, A. (2019). *Data visualization: A handbook for data driven design*. SAGE.

Lankes, M., Maurer, B., & Stiglbauer, B. (2016). *An eye for an eye: Gaze input in competitive online games and its effects on social presence* [Paper presentation]. Proceedings of the 13th International Conference on Advances in Computer Entertainment Technology. Association for Computing Machinery.

Liang, W., Lu, Z., Jin, Q., Xiong, Y., & Wu, M. (2015). *A temporal model of research work tracking and assessing for an individual and a group* [Paper presentation]. 2015 IEEE International Conference on Smart City/SocialCom/SustainCom (SmartCity) (pp. 440–445). https://doi.org/10.1109/SmartCity.2015.110

Luff, P., Heath, C., & Svensson, M. S. (2008). Discriminating conduct: Deploying systems to support awareness in organizations. *International Journal of Human–Computer Interaction*, *24*(4), 410–436. https://doi.org/10.1080/10447310801920490

Mankoff, J., Dey, A. K., Hsieh, G., Kientz, J., Lederer, S., & Ames, M. (2003). *Heuristic evaluation of ambient displays* [Paper presentation]. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (pp. 169–176). ACM.

Markopoulos, P., & Mackay, W. (2009). *Awareness systems: Advances in theory, methodology and design*. Springer Science & Business Media.

Montag, C., Flierl, M., Markett, S., Walter, N., Jurkiewicz, M., & Reuter, M. (2011). Internet addiction and personality in first-person-shooter video gamers. *Journal of Media Psychology*, *23*(4), 163–173. https://doi.org/10.1027/1864-1105/a000049

Montané-Jiménez, L. G. (2016). *Presencia Social en Sistemas Groupware* [Unpublished doctoral dissertation]. Universidad Veracruzana.

Montané-Jiménez, L. G., Benitez-Guerrero, E., Mezura-Godoy, C. (2013). *Context-aware groupware systems and video games: State of the art* [Paper presentation]. Proceedings - 2013 Mexican International Conference on Computer Science, ENC 2013 (pp. 55–59).

Montané-Jiménez, L. G., Benítez-Guerrero, E., Mezura-Godoy, C., & Pino, J. A. (2015). *Measuring social presence in groupware systems* [Paper presentation]. 2015 IEEE 19th International Conference on Computer Supported Cooperative Work in Design (CSCWD) (pp. 200–205). https://doi.org/10.1109/CSCWD.2015.7230958

Nova, N. (2002). *Awareness tools: Lessons from quake-like* [Paper presentation]. Proceedings of Playing with the Future Conference (pp. 5–7).

Pouryazdan, M., Kantarci, B., Soyata, T., Foschini, L., & Song, H. (2017). Quantifying user reputation scores, data trustworthiness, and user incentives in mobile crowd-sensing. *IEEE Access*. *5*, 1382–1397. https://doi.org/10.1109/ACCESS.2017.2660461

Robertson, S., Back, N., & Bartlett, J. D. (2016). Explaining match outcome in elite Australian rules football using team performance indicators. *Journal of Sports Sciences*, *34*(7), 637–644. https://doi.org/10.1080/02640414.2015.1066026

Sacha, D., Senaratne, H., Kwon, B. C., Ellis, G., & Keim, D. A. (2016). The role of uncertainty, awareness, and trust in visual analytics. *IEEE Transactions on Visualization and Computer Graphics*, *22*(1), 240–249. Jan https://doi.org/10.1109/TVCG.2015.2467591

Schneiderman, S. (1999). *Information visualization: Using vision to think*. Morgan Kaufmann.

Schroeder, R. (2002). *Copresence and interaction in virtual environments: An overview of the range of issues* [Paper presentation]. Presence 2002: Fifth International Workshop (pp. 274–295).

Sedig, K., Parsons, P., Dittmer, M., & Haworth, R. (2014). Human-centered interactivity of visualization tools: Micro- and macro-level considerations. In *Handbook of Human Centric Visualization*. (pp. 717–743). Springer.

Shen, K. N., & Khalifa, M. (2009). Design for social presence in online communities: A multidimensional approach. *AIS Transactions on Human-Computer Interaction*, *1*(2), 33–54. https://doi.org/10.17705/1thci.00006

Standard, I. (2010). *Ergonomic of human-system interaction – Part 210: Human-centred design for interactive systems* [ISO No. ISO 9241-210: 2010]. ISO.

Storey, M.-A D., Čubranić, D., & German, D. M. (2005). On the use of visualization to support awareness of human activities in software development: A survey and a framework. In *Proceedings of the 2005 ACM Symposium on Software Visualization* (pp. 193–202). ACM.

Torres, A., Montané-Jiménez, L. G., Castillo-Peralta, M. (2019). *Towards team performance visualization in collaborative systems* [Paper presentation]. 2019 IEEE International Conference on Engineering Veracruz (ICEV) (Vol. I, pp. 1–5).

Tran, M. H. (2006). *Supporting group awareness in synchronous distributed groupware: framework, tools and evaluations*. Swinburne University of Technology, Faculty of Information & Communication Technologies.

Truemper, J. M., Sheng, H., Hilgers, M. G., Hall, R. H., Kalliny, M., & Tandon, B. (2008). Usability in multiple monitor displays. *ACM SIGMIS Database*, *39*(4), 74–89. https://doi.org/10.1145/1453794.1453802

Wang, Y., Gräther, W., & Prinz, W. (2007). Suitable notification intensity: The dynamic awareness system. In *Proceedings of the 2007 International ACM Conference on Supporting Group Work* (pp. 99–106). ACM.

Ware, C. (2012). *Information visualization: Perception for design*. Morgan Kaufmann.

Xu, C., Zheng, Y., Hu, H., & Li, Y. (2016). *Measuring and visualizing individual contributions in online collaborative discussions* [Paper presentation]. 2016 IEEE 16th International Conference on Advanced Learning Technologies (ICALT) (pp. 176–180). https://doi.org/10.1109/ICALT.2016.93

About the authors

Maria Teresa Cepero has a Master's Degree in User-Centered Interactive Systems from the Universidad Veracruzana. She is currently pursuing a PhD in Computer Science from the Universidad Veracruzana in Mexico. Her areas of interest are: Computer-Supported Cooperative Work (CSCW), Human-Computer Interaction, Data visualization and Smart Cities.

Luis G. Montané-Jiménez PhD in Computer Science graduated from the University of Veracruz (UV) in Mexico, with a master's degree in Applied Computing. He is full-time professor with the Faculty of the Statistics and Computer Science of the UV. His research interests are the Computer-Supported Cooperative Work (CSCW) and Human-Computer Interaction.

Guadalupe Toledo-Toledo Research professor at the University of the Isthmus, master in computer applied by the national laboratory of advanced computer science in Xalapa, Veracruz, Mexico, his areas of interest are in software development involving disciplines such as software engineering, human computer interaction, virtual and augmented reality, data mining, databases, artificial intelligence.

Betania Hernández-Ocaña Ph.D. degree in computer science from the Universidad Juárez Autónoma de Tabasco, México, in 2016. She is currently a Research Professor with the División Académica de Informática y Sistemas, Universidad Juárez Autónoma de Tabasco, México. Her areas of interest are related to swarm intelligence algorithms and evolutionary, global optimization, and constraint-handling.

Carlos Alberto Ochoa Degree in Computer Science from the Universidad Veracruzana, with a master's degree in Computer Science from the Arturo Rosenblueth Foundation. With current recognition of prodep profile. With certification in Networks by Microsoft. Professional experience in the area of Servers and experience in university management.